Forecasting the Ocean Optical Environment in Support of Naval Operations (NP33)

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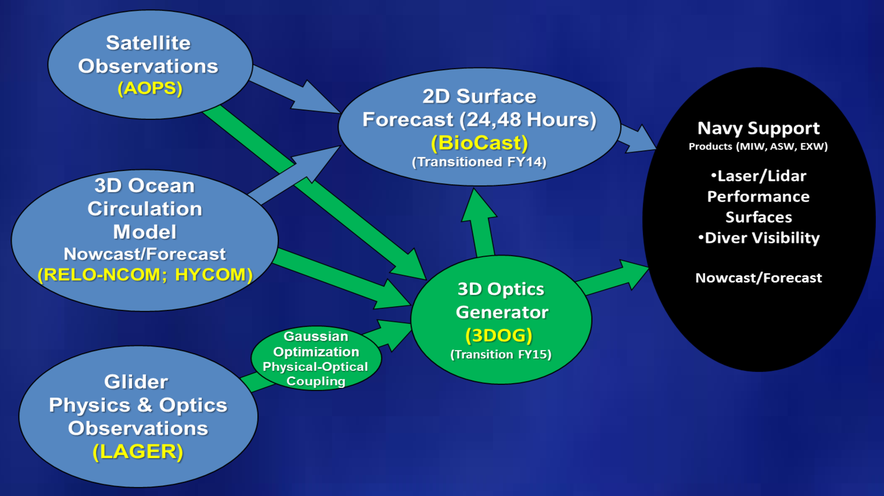
I. Abstract

TODS (Tactical Ocean Data System), an ocean optical forecasting system, is currently being developed by the Naval Research Laboratory (NRL) to provide NAVOCEANO with the capability to generate 3D optical forecast products for laser/LIDAR performance surfaces and to support diver operations. These products are required to support mine counter measure activities for detection of mine-like objects and identification of mines and can also be very useful in supporting Anti-Submarine Warfare (ASW), Mine Warfare (MIW) and Naval Special Warfare (NSW) activities. TODS will ultimately fuse optical profiles from gliders and Battle Space Profiles (BSP's), surface satellite optical properties, and ocean forecast circulation model fields to predict the future state of the 3D optical environment. The main forecasting component of TODS is the Bio-Optical Forecasting System (BioCast) model. BioCast provides the U.S. Navy with short-term (24 to 48 hours) forecasts of the ocean's surface physical and optical environments and is currently undergoing operational testing (OPTEST) at NAVOCEANO with NRL-Stennis help and participation. The forecasts are generated using surface ocean optical properties derived from ocean color satellite data as initialization fields. BioCast then ingests operational circulation model currents and physics forecast fields and generates corresponding optical property forecast fields. BioCast validation statistics, generated via forecast comparison to "next-day" satellite images, show improved performance over 24-hour persistence of composited satellite data. Future work and improvements will include generation of 3D optical/physical forecast volumes with the use of optical profile data and model-generated physics profiles by another TODS component, 3D Optical Generator (3DOG). These 3D optical forecast volumes, including subsurface optical information such as layers in the water column and bottom resuspension, will then be combined with performance algorithms for LIDAR systems and diver operations to determine optimal deployment, planning and strategy. 3DOG is currently undergoing operational evaluation at NRL and will be transitioned to NAVOCEANO in the near future. TODS will ultimately provide the Navy with a capability to couple the 3D optical environment with system performance and diver visibility algorithms to generate tactical decision aids and for operational planning increases timeliness and efficiency in clearance operations in MIW, and potential ASW and NSW/EXW. The overall … ve tool for the 3D optical battlespace in s…

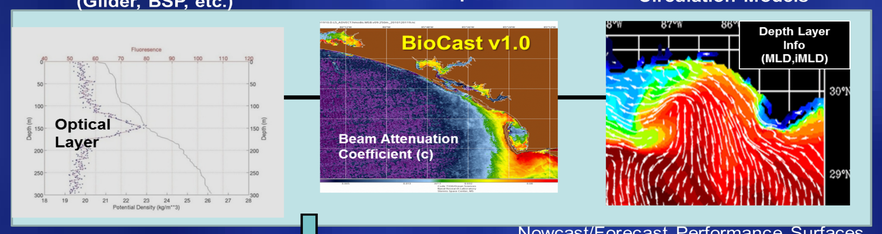
II. Tactical Ocean Data System

Fusion of Satellites, Glider Data and Physical Models In Support of Mine Warfare Operations



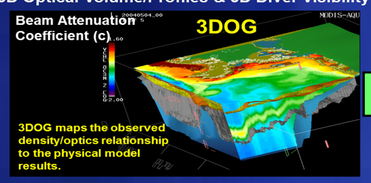
"Defining the optical environment for Navy Systems"

Vertical Optical Profiles (Glider, BSP, etc.) | Nowcast / Forecast Satellite Optics BioCast/OpCast | Nowcast / Forecast Circulation Models



Nowcast/Forecast Performance Surfaces

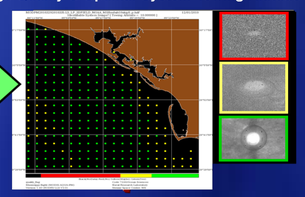
3D Optical Volume/Profiles & 3D Diver Visibility



AQS24 Performance Model

Beam Attenuation Coefficient (c)

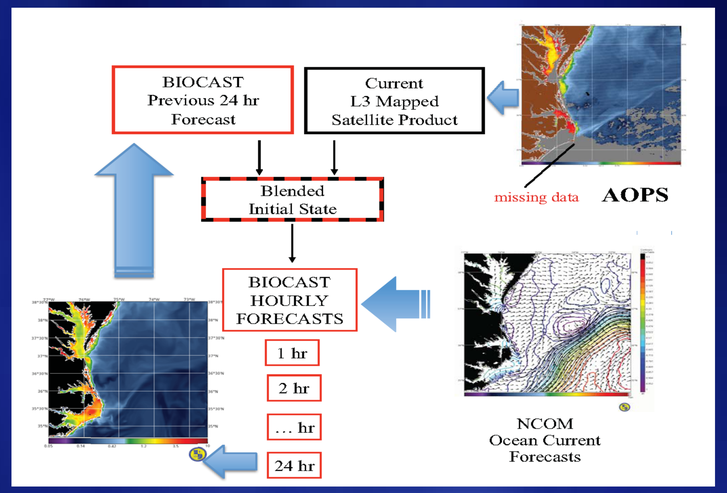
Image Quality & Optimal System Towing Altitude



Insitu Physics/Optics Used to Tune Coeffs in 3DOG

III. BioCast v1.0 Operational Procedure

Transitioned to NAVO July 2014 / VTR Accepted / OPTEST underway



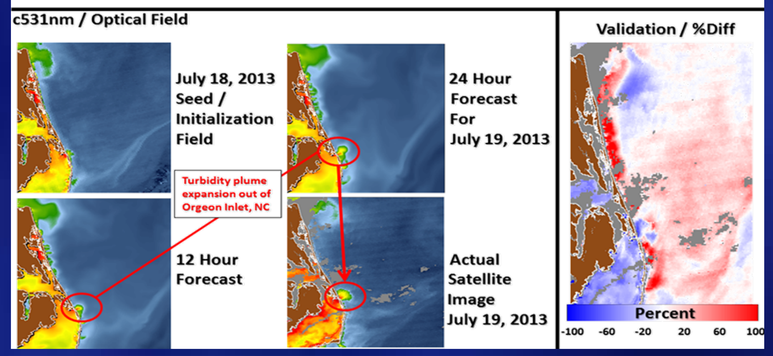
- **The observed (satellite) bio-optical property is the state variable derived from satellite radiance and directly updated with each new observation (daily).**
- **Operational Ocean Circulation Models provide velocity forecasts used for transport calculations.**

IV.Forecasting the Surface Bio-Optical Properties BioCast Evaluation

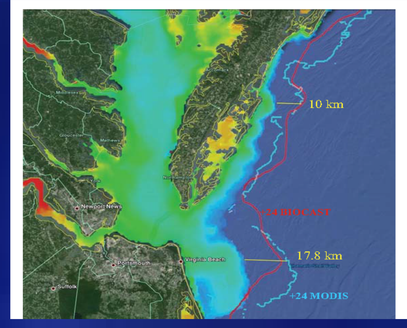
Trident Warrior - Chesapeake Bay, VA – *July 18, 2013*

Forecast Steps:

Seed the Model with Satellite Bio-Optical Products → Advect Satellite Properties forward (hourly steps) Conservative Tracers → Compare with Next Days Satellite Bio-Optical Products

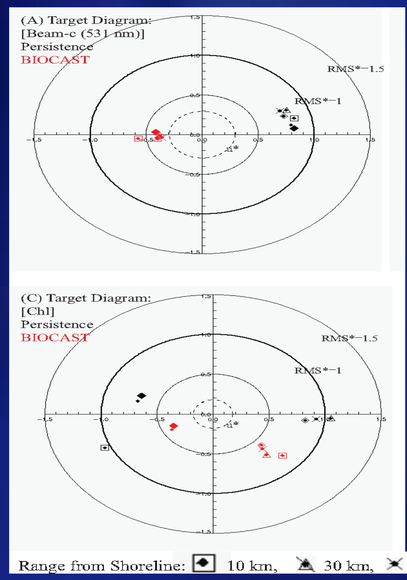


Example of BioCast processing for Chesapeake Bay, Virginia during the Trident Warrior exercise using the MODIS satellite product for the beam attenuation (proxy for turbidity) coupled with the currents derived from RELO-NCOM, BioCast enables the currents to advect the turbidity pixel information, generating a picture of future turbidity distribution. Differencing the BioCast product from the actual next day's image provides insight into the uncertainty of the BioCast model. Note in this case, BioCast successfully forecasted the observed expansion of the plume out of Oregon Inlet, NC into the Atlantic Ocean.



Chesapeake Bay, VA forecast results showing beam attenuation contours for the initial state (July 18, 2013) and +24 hour forecast (July 19, 2013). All contours represent an optical iospleth c531nm = 0.4 m-1. The 24 hour marks (red = biocast, blue = modis). The yellow distance markers indicate the seaward expansion.

IV. Continued



Statistical summary diagrams comparing 30-day latest composites (persistence) against the next-day MODIS satellite product (black) and BioCast 24-hour forecast against the same next day MODIS product (red). Statistics are generated from 61 days of "next-day" comparisons (July 2 – August 31, 2013). The Range refers to the subset of image pixels selected for statistical analysis using a distance from shoreline criteria. RMS* is the RMS normalized to the reference standard deviation.

The bullseye (RMS=0) would mean a perfect match between persistence or the 24 hour forecast as compared to the next days image. Note that the BIOCAST 24 hour forecast comparison to next day's image (red) is closer to bullseye than persistence.

Range	10 km	30 km	60 km	109 km	209 km	249 km
C (531 nm) MAD Persist. (m^{-1}) x 10^{-2}	29.80	17.17	10.95	8.37	6.57	5.93
C (531 nm) MAD BIOCAST (m^{-1}) x 10^{-2}	17.80	8.00	4.88	3.78	3.08	2.76
BIOCAST-C (531 nm) Difference Reduction (%)	40.3	53.4	55.4	54.8	53.1	53.5
Horizontal Diver Visibility MAD Persistence (m)	2.30	3.98	4.13	4.32	4.29	4.26
Horizontal Diver Visibility MAD BIOCAST (m)	1.50	1.63	1.73	1.73	2.04	1.97
BIOCAST-Diver Vis. Difference Reduction (%)	34.8	59.0	58.1	60.0	52.4	53.8
N (number of comparisons) =	2532	11046	23039	35757	54110	65337

Table provides a summary of the MAD performance statistics for the beam attenuation (beam c) and horizontal diver visibility products. BioCast reduces the MAD for beam attenuation c(531) by an average of ~51% over the various pixel inclusive ranges from the coastline selected (10 – 249 km; Table 1). Beam-c values were also converted to horizontal diver visibility estimates to place the MAD statistics in more Navy relevant terms. Again, the mean forecast field departure from observation is reduced by approximately half when BioCast is used in place of persistence.

V. Summary / Future Transitions

The BioCast model is shown to be capable of generating operational quality data in a time frame that supports the military demand. Results indicate BioCast should provide an extension of the current optical products produced by NAVOCEANO. The model output appears reasonably well characterized however remain subject to the uncertainty inherent to the input data sources. Continuous Cal/Val procedures are recommended to monitor imagery sensor performance and product data to keep a handle on uncertainty in those data sources. Meteorological forecasting has been shown to have a critical impact on mission success. Similarly ocean predictions can be a critical enabler for naval operations. Follow-on transitions will include generation of 3D optical/physical forecast volumes with the use of optical profile data and model-generated physics profiles via the 3D Optical Generator (3DOG). 3DOG includes system performance models and currently undergoing op-eval and validation at NRL.